(1) With the author's compliments

(Crop Disease and Pest Series, No. 7.) 1903

A. D. Cotton

THE AGRICULTURAL LEDGER.

1903—No. 4.

SOLANUM TUBEROSUM.

(POTATO DISEASE.)

[*DICTIONARY OF ECONOMIC PRODUCTS, Vol. VI., Pt. I. S. 2330.*]

POTATO DISEASES OF INDIA.

By E. J. BUTLER, M.B., *Cryptogamic Botanist to the Government of India.*

Other DICTIONARY articles that may be consulted:

Fungi and Fungoid Pests, *Vol. III.*, F. 745.

also

The Agricultural Ledger, 1893, No. 4; 1895, No. 20.

CALCUTTA:
OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA.
1903.

Price 4 annas or 4d.

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1903—No. 4.

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(Crop Disease and Pest Series, No. 7.)

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POTATO DISEASES OF INDIA.

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INTRODUCTION.

INTRODUCTION.

There exists in India a good deal of scattered information regarding the occurrence of various diseases of potatoes in the country. This information is, however, somewhat difficult of access to those most directly interested, being buried in Departmental records or found here and there in the Proceedings of Societies or in Scientific Journals. Furthermore there is much misconception of the extent to which disease is responsible for the generally poor quality which characterises the native-grown vegetable. This may be found not alone in the mind of the native cultivator, who, as is his way, puts down every untoward circumstance that afflicts his crop to a deficiency or an excess of rainfall, but also amongst Europeans who may happen to be brought into touch with potato-cultivation and who incline to ascribe all failings to the agricultural shortcomings of the raiyat. No doubt the climate and the methods of the cultivator have something to do with the state of affairs, but I think it can be shown that the use of tainted seed year after year and the consequent prevalence of disease almost universally throughout the country is a far more

Literature not readily accessible.

Mistaken views as to cause of poor quality.

Result following use of tainted seed.

INTRODUCTION.

important factor. Again, even where specific disease is recognised to exist and is not confounded with unfavourable climatic conditions, the cultivator admits his helplessness and wrongly believes in the futility of precautionary measures. So mad a practice as that recorded below from Farukhabad, where the diseased tubers of one year's crop are habitually set aside for the next season's seed, can only be explained by a total want of understanding of the particular circumstances which give rise to disease and a fixed idea that such things are beyond control. For one does not find the cultivator as a general rule adopting practices, knowingly, which will result in an inferior crop. Once show him that he can diminish his losses from disease by a certain practice, or by the growth of a particular variety, and he eagerly avails himself of the information. In Poona the produce of the newly imported seed on the Government Farms which at first resisted the blight prevalent in that neighbourhood, was rapidly bought up at prices far exceeding that which any other seed would fetch. Therefore, that in many places disease is allowed to prevail unchecked, without the slightest effort to control it or to mitigate its effects must be due more to ignorance of the means than to a want of appreciation of the necessity. But it so happens that experience gained in many countries has proved the potato to be one of the crops that most repays the treatment of its diseases. Not only has the use of Bordeaux mixture for the **Phytophthora** blight proved efficacious in saving the crop in bad years; but it has been found that the practice of spraying is agriculturally a sound one, even when no disease appears. For, on account of some action not yet quite understood, the use of the fungicide increases the size and weight of the tubers, and the value of the additional yield thus obtained about covers the cost of the application. It is a case of Accident insurance in which the premium is returned each year. In many of the potato-growing districts of France, Belgium, and America, spraying has now become one of the routine operations of cultivation, and it may be said to have passed into an axiom in these countries that in the successful cultivation of potatoes, successful treatment of disease occupies the first place. It is perhaps too much to hope that spraying is a practice likely to be widely adopted in India, at any rate in the near future, but it is, fortunately, not the only means by which disease may be lessened. The choice of seed, the control of irrigation and a number of measures directed to improve what may be called the sanitation of the plant are but little less important, and it is in the observance of these that I believe lies the chief hope of dealing with severe outbreaks of disease.

Ignorance of disease and fatalistic notions of local cultivators.

Imported seed raised at Poona.

Potato disease amenable to treatment.

Spraying improves the tubers.

Largely practised out of India

Potato Diseases of India. (*E. J. Butler.*) **SOLANUM tuberosum.**

INTRODUCTION.

For the reason that it appeared to be of interest to endeavour to give a historical account of the appearance of disease in Indian potatoes so far as the imperfect records go, and to give some idea of the extent and nature of the blights, I have gathered together the information to which I have had access. I have also had occasion recently to examine a considerable number of specimens of diseased plants from various parts of India, which have enabled me to check the information thus gained and in several cases to add to it. The examination of these specimens shows that disease of one kind or another is present almost wherever potatoes are grown in the country. In the more humid areas such as Assam, Bengal, the Eastern Himalayas and the Nilgiris, the prevailing blight is, as might be anticipated from its known preference for damp climates, that caused by the deadly **Phytophthora**. In the drier climates of the Deccan and Gujarat the so-called "Bangle blight" is found. But while the former appears to be steadily increasing its area of distribution and to be acclimatising itself to districts such as the plains of Bengal, where one would not have expected it to survive, the latter appears to spread more slowly, if at all. It has certainly failed to obtain a footing in Bengal though introduced there several years ago. These two are the most important diseases but several others are found. Since their distinction is necessary for the treatment, which varies in each individual instance, an account of the signs by which they may be recognised has been given. It must be admitted, however, that without the microscope, diagnosis is often difficult or even impossible, and in cases of doubt it is better to obtain an expert opinion. Finally, a summary of the treatments adopted in other countries and of the "Sanitary" precautions found advisable (such as the methods of storing recommended where the presence of diseased tubers is feared), is added. It is not to be expected that these recommendations will be found, as they stand, entirely adapted to Indian conditions, but they should certainly be capable of modification, in intelligent hands, in such a manner as to admit of application to particular cases. The only series of systematic experiments connected with these diseases that has been carried out in this country, so far as I am aware, should be of great value as a guide. I refer to the experiments undertaken at Poona in 1892 and 1893 with regard to the "Bangle blight" of that district, by the Department of Land Records and Agriculture, Bombay.

In India disease is generally prevalent.

Phytophthora, "Bangle" Blight.

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CHAPTER I.

Potato blight caused by the fungus Phytophthora infestans *de Bary.*

First appearance.

1. ***History of the disease.***—The disease which is universally known as the "Potato disease," though by no means the only one to which potatoes are liable, first attracted general attention in Europe in 1845. For several years previous to this, references to a disease in potatoes were common in many countries: in France, Belgium and Germany in 1840 and 1841; in Norway, Denmark and the United States in 1842, in which year also an account of it was published by C. von Martius in Munich; in Canada and Italy in 1844 when it was evidently well established in most countries in the Old World and in North America. In 1845 a terrible wave of epidemic disease swept through every country from Russia westward to Canada, reaching in several to the height of a national calamity. It is said that in September of that year it was almost impossible to procure sound potatoes in England. Since then the pest has never quite disappeared in the area affected, fluctuating with respect to the virulence of its attacks in a remarkable manner. Of all the countries within that area Ireland has perhaps suffered most. There the disease is well known to have been the exciting cause of one of the worst famines of modern times amongst a population whose staple food was potatoes. In 1879 again the loss in Ireland from an exceptionally bad year was estimated at nearly £6,000,000. It still continues to be one of the worst diseases of cultivated crops with which the agriculturists of that country have to contend. Elsewhere, however, the virulence has decreased, owing in a great measure to the care with which the seed is now selected, and at the present day, in America at least, potato growers are able to keep it under reasonable control.

Connection with a fungus.

2. Though Montaigne and Berkeley in 1845 discovered the causal connection between a fungus and the disease, this view was not at first accepted. In 1846 prizes of £50, £30, and £20 were given by the Royal Agricultural Society of England for studies of its cause and treatment, and were awarded to investigators, who held that a fungus had nothing to do with it. Even in 1872 for a prize of £100 offered by Earl Cathcart, President of the Royal Agricultural Society, not one of the 94 essayists had a correct idea of its nature. In 1876, however, Professor de Bary re-established in a conclusive manner the fungal cause already indicated by him in 1863[1], and potato-growers in

[1] De Bary, Journal of the Royal Agricultural Society of England, Vol. XII, 1876, and "Recherches sur le developpement de quelques champignons parasites" in Annales des sciences naturelles, 1863.

every country have been enabled, mainly by the work of the German scientist, to deal with the matter with a full understanding of its nature.

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3. In India, the Nilgiris appear to have been the first locality affected. The Honorary Secretary, Nilgiri Agri-Horticultural Society, writes to me (August 19th, 1902) in answer to an enquiry regarding the blight in that district:—

Nilgiris first locality affected in India.

"The disease is no doubt the common Irish Potato blight, caused by a fungus. It has been noticed on these hills for the past 25 to 30 years, especially on the low-lying drained swamp lands. On new land and with carefully selected seed the damage is but little, though generally the disease is increasing. New imported tubers have been frequently introduced, and potato seed has been imported—not tubers—but these new plants are subject to the disease, unless entirely segregated on new land.

"It is considered useless to combat the disease, when once noticed on a field, with chemical sprays or otherwise—the fungus spreads so rapidly and is so general. It seems almost the same with the coffee leaf disease, for which no cure can be found, beyond high cultivation and manure to support the trees through the attacks."

Experience in the Nilgiris.

4. There appears to be a general agreement amongst the members of the Nilgiri Agri-Horticultural Society that the disease prevalent in these hills is the common European one. Though we shall see later that another potato disease is known to exist in the neighbourhood of Ootacamund, still I think the above-mentioned view is correct. I have had no opportunity of personally seeing the blight, but a letter of **Major-General H. R. Morgan** printed in the Proceedings of the Society for the 10th August 1900, makes it very probable that **Phytophthora** really occurs there. In this, he states that, about ten years ago, the disease was so bad in some potatoes, the seed of which had been obtained from a large nurseryman in England, that even his tomatoes were affected. **Phytophthora** has been known in many cases to spread from potatoes and to attack the tomato, whereas the other serious Indian potato disease—Bangle blight—is not known to do so.

5. In a note on the disease, dated 11th August 1902, communicated to me by the Honorary Secretary, Nilgiri Agri-Horticultural Society, **General Morgan** says:—

Disease not known 40 years ago.

"Some 40 years ago there was no potato disease but then the tuber was only cultivated in certain places such as Kaity, Kulhutty and a few other places. I cannot say when the disease first appeared, probably about 25 years ago, since which time the cultivation of the potato has become almost universal amongst the Badagas, the Subbies buying the produce. In the last three years the disease has spread. It appears as a blight, the plants droop and bear but small

Badaga cultivators.

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tubers. I soaked my seed potatoes in a solution of sulphate of copper, strength about 5 per cent; this had some effect. I also powdered the stalks when drooping with sulphur. The Badagas use no remedy and suffer accordingly."

Deterioration of produce.

6. In the *Proceedings of the Nilgiri Agri-Horticultural Society* reference is made from time to time during the past few years to the deterioration of potatoes in the district. It is generally attributed to inferior seed, continued cultivation in the same fields, and disease. The Badaga cultivator seems to be quite aware of the value of new seed and tries to get it from Bangalore; but he is habitually cheated, some of his own crop being held over from last season and re-sold to him as good Bangalore seed. A more potent method of inducing disease could not be imagined, for apart from the danger of seed-infection, the potato is one of the plants which most require constant change of seed to preserve its vitality and power of resistance to disease.

Need for fresh seed.

7. In a letter regarding the establishment of an experimental garden in the Nilgiris, from C. M. Mullaly, Esq., I.C.S., Acting Collector of the Nilgiris, to the Secretary to the Commissioner of Revenue Settlement Land Records and Agriculture, Madras, dated 1st September 1901, and printed in the *Proceedings of the Nilgiri Agri-Horticultural Society's Meeting* of October 25th, 1901, it is stated that potatoes form a very large proportion of the Badaga cultivation, and that it is scarcely possible to get any really good potatoes in the district, nearly all being diseased by a fungus.

Good potatoes not now found in the Nilgiris.

Disease very prevalent.

8. It is certain therefore that disease is very prevalent in the Nilgiris and is extending its ravages, and a part at least of the damage is to be attributed to **Phytophthora**.

Introduction by imported seed.

9. From what is known of similar cases it is probable that the fungus was first introduced there in imported seed from Great Britain. Infection of the tubers usually occurs, as will be described below, while the disease runs its course, and the planting of infected tubers is perhaps the most frequent method of propagating the pest. It has been ingeniously supposed that the first introduction of the disease into Europe took place from South America, the home of the potato, on the shortening of the time required to convey tubers from the New World to the Old by the introduction of steam. The disease is known to occur in the Andes, and probably **Phytophthora infestans** existed there for centuries before its appearance in Europe as a parasite on the wild species of **Solanum** which were the ancestors of our cultivated plant. That it was not known in Europe at an earlier period in the cultivation of the potato has been supposed to be due to the fact established by Jensen, that exposure to a temperature of over 77°F. for any length of time is fatal to the

Original home of the disease.

fungus. Until the introduction of steam the parasite was unable to cross the zone of tropical temperatures intervening between the Andes and Europe. The advance of the disease has been eastward since that time, and it seems probable that it has been conveyed into India in somewhat the same fashion as into Europe. In Australia, separated from Europe as it is by a long stretch of high temperatures, **Phytophthora** is probably as yet unknown, a disease at first supposed to be the common European one having been shown by **Mr. Tryon** in Queensland, to result from a bacterium within the tissues of the stem.

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Spread dependent on temperature.

10. Darjeeling appears to have been the next locality infected in India. Potato cultivation in the hills of that district had long been of considerable importance. Before 1883 many thousand maunds were annually exported to the plains. In 1884, 14,500 maunds were so exported.* Since that time potato cultivation has very greatly declined, and this has been almost entirely due to disease, which broke out first in 1883, shortly after the introduction of English varieties to Darjeeling. The disease spread through the district and Sikkim and is reported to cause serious damage also in the adjoining States of Nepal and Bhutan. As we will see below, it has not remained confined to the Eastern Himalayas but has spread westward as far as the Kumharsain State, north of Simla, and eastward to Assam. Cultivation of English potatoes is stated by **Babu N. C. Choudhury** to have extended all through Sikkim and into Nepal and Bhutan, the tubers being largely sold in the Darjeeling market for the use of the European residents.

Darjeeling next infected.

Decline of potato cultivation.

Extension in the Himalayas.

11. In the introduction of any large quantity of seed tubers from an infected area, such as Great Britain, the danger of introducing disease is far greater than appears on the surface. And this for two distinct reasons. In the first place, even in years of slight damage from disease, the fungus can still be found on searching almost everywhere that potatoes are largely grown. For some reason, not yet explained by our present conception of the factors which induce epidemic disease, but certainly in part related to climatic influences, a time comes when the plant fails in its yearly struggle. Then we speak of a bad year for disease. It would be incorrect to assume that the failure is connected in any way with an unusual

Danger of importing seed.

Annual struggle against disease.

* Some of these particulars are taken from a "Note on experiments in potato cultivation in the Darjeeling Hills" by Mr. B. C. Basu of the office of the Director, Department of Land Records and Agriculture, Bengal, communicated to me by that Department. In this note also a brief account is given of experiments in checking the blight undertaken by the Department in 1888 to 1891, which however, owing to a combination of unfavourable circumstances, gave little practical results.

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prevalence of the fungus at the beginning of the year. Circumstances have been favourable for its multiplication and that is all. In other years, when damage has been slight, it is probable that as many foci exist from which the fungus may spread in the early part of the year as exist in the worst years of epidemic. But circumstances are against spreading and general disease does not occur. In other words every year is potentially a bad potato year in an infected country. A moment's thought will show that this must be due to a persistence of the fungus from year to year even when no outbreak of disease occurs to mark its presence. We will see below that the only way in which this can occur in the light of our present knowledge is by fungus infection of the tubers. Even in good years, then, a tuber here and there will be infected, and we have no means of separating the good from the bad before exportation. A second reason why importation is dangerous is that it is far from easy to discard diseased potatoes at the time of planting. Small tubers, at least, are usually set whole, and it is just these small ones which are liable to contain the fungus, since one of the effects of the disease is a stunting of the growth of the tubers. Even where sets are rigorously cut before planting, it is not certain that the presence of the fungus can always be detected by a blackening of the tissues.

Persistence of fungus in the tubers.

Some tubers always tainted.

Difficulty of discarding tainted tubers.

12. In any large import of seed from an infected area there is, then, at least a possibility and perhaps a probability of an introduction of the fungus. All that is wanting, afterwards, is a congenial locality for the establishment of the disease.

Conditions in Sikkim suitable to disease.

13. Such a locality appears to have been furnished in the Sikkim Himalayas. A few years after the introduction of the new seed, complaints of disease were general. For some time the native potatoes suffered most, appearing to be particularly weak in resisting the invasion of the fungus, but eventually, by 1886, deterioration set in also in the imported varieties, and in the Report of the Royal Botanic Garden, Calcutta, for 1886-87, it is stated that the acclimatised English potatoes of the Lloyd Botanic Garden, Darjeeling, had proved a failure. In the Report of the same institution for 1887-88, English tubers are said to be particularly liable to attack, and it is recommended that seed from Malta, Australia, or elsewhere, where the conditions of growth differ less widely from those in the Indian hills, be imported rather than English ones. The experience noticed here of the plant by which disease is introduced, itself proving for a time less liable to the disease than the native varieties of the locality, is not uncommon, and cannot be used as an argument in favour of the pre-existence of the fungus in Sikkim. Judged by its results, this well-meant effort at improving the quality of the crop must be held to have been most unfortunate.

Native potatoes first affected.

Deterioration of the new seed.

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14. Eastward the disease is next reported from Assam. In a note on "The Prevalence of Potato diseases in Assam," kindly supplied to me by Mr. B. C. Basu, Assistant to the Director, Department of Land Records and Agriculture, Assam, 1885 is stated to be the date of the first appearance of the blight in the Khasi Hills. In 1887 it raged in a virulent form, and almost the whole of the crop was destroyed. Planting on new land was advised, and the disease somewhat checked. In 1892 Dr. D. D. Cunningham, Special Assistant to the Sanitary Commissioner with the Government of India, examined specimens of the disease from the Khasi Hills and identified the fungus as **Phytophthora infestans**. In 1899 disease was again virulent in the hills, but was checked at the Government Experimental Farm, at Upper Shillong, by Bordeaux mixture. Next year, however, the application of this preventative was unsuccessful owing probably to excessive rainfall, and the crop was defoliated. Some of the tubers from this crop were examined by me in April 1901, but beyond blackening of the tissues nothing definite was found. In July 1902 further specimens of complete plants were received from Shillong and **Phytophthora** found in quantity on the under-surface of the leaves. The history of the attack in this case was similar to that of the previous year, the crop dying out several weeks before it was due to ripen. The leaves turned black and fell off with great rapidity, so that within a week or ten days the entire crop was stripped, leaving the green stalks standing quite bare. Though it was stated that when forwarded the tubers were not discoloured, still on receipt in Dehra Dun, 50 per cent. were found blackened in the interior, a result corresponding with the observations of the previous year. Bordeaux mixture was again unsuccessful, owing no doubt to heavy rainfall.

Disease in Assam.

Virulent in 1887.

Identification of the fungus.

Treatment.

Nature of attack.

15. In the Reports of the Department of Land Records and Agriculture, Assam, it is noted that imported seed from other districts often resists the disease for some years, eventually succumbing when apparently established. This important fact will be returned to again. The crop from which the diseased sample sent to me was taken was raised from acclimatised Naini Tal seed, the original seed stock having been imported into the district several years ago. Some half dozen other kinds of potatoes raised from newly imported seed on the Farm, did not show the brown spots, and were quite healthy. Interesting information is also given in these Reports and by Mr. Basu, regarding the methods of cultivation in the Khasi Hills. Two crops are usually got in the year, the same land being used constantly year after year. The second crop is generally poor and is largely used to supply the next season's seed. Small tubers are much used for seed, and though the Khasia cultivator recognises blackening as a sign of disease, blackened tubers are freely used in

Resistance of new seed.

Khasia cultivation.

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planting. Small tubers are planted whole and are probably often diseased. No precautions whatever appear to be taken against the disease, and it is not surprising that "bad years" are frequent. In every respect the cultivation practised in Assam must favour the pest.

Probable infection from Sikkim.

16. The first outbreak of disease in Assam, two years after its appearance in the Sikkim Himalayas, points to infection from that source, either by exportation or by continuous extension through Bhutan.

Disease in Nepal.

17. In the other direction, westward, along the Great Range, the disease has also progressed. It is reported to have extended through Nepal. **Dr. Cunningham** in a paper on "Blights affecting Potato-crops in India" published in the *Scientific Memoirs by Medical Officers of the Army of India*, in 1897, mentions that he had received specimens of **Phytophthora** from Kumaun. This proves that it has reached that locality. I have been unable to obtain definite information as to the extent of its ravages in this district, which is a large exporter of Potatoes. The Deputy Commissioner of Almora reports that a potato disease which appears to be Irish blight (**Phytophthora**), occurs at times in the Almora district. The Deputy Commissioner of Naini Tal states that "about 20 years ago" (*i.e.*, about the time of the introduction of the disease into Darjeeling) "a blight destroyed nearly the whole of the crop of this district. In the vernacular it was simply said, 'Hawa se mar gaya.' Since then the species attacked apparently became extinct, or at any rate the fungus does not seem to have attacked the crop again. Other cultivators report what seems to be the supertuberation noted by **Mr. Seers**" (see below), "with consequent unhealthy condition of the crop, but anything like general disease has been unknown."

Disease in Kumaun.

18. **Mr. Seers**, Proprietor, Snow View Garden, Naini Tal district, writes in answer to the Deputy Commissioner's enquiries that "no such thing as Irish blight so-called exists in this Province." This is obviously a mistaken assertion for we have seen that **Dr. Cunningham** obtained it from there. If any one fact, in connection with **Phytophthora** is fully established, it is that the fungus does not leave a district which suits it, when once it has gained an entry into it as long as conditions of cultivation are unchanged; and probably no change short of entirely ceasing to grow potatoes could altogether exterminate it. The fungus is found in the Himalayas, east and west of Kumaun, and must certainly exist in Kumaun itself. That it does not cause extensive damage there, is a fact for which the cultivators have reason to be thankful. But it must be an ever-present danger.

Supertuberation in Kumaun.

19. While stating that any general specific disease does not occur in Naini Tal district, **Mr. Seers** remarks on a fact which gives a possible explanation of the failure of Naini Tal seed, in the last two or three years, in Lower Bengal. A late monsoon has, for several seasons, induced supertuberation in a great part of the crop

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in Kumaun. Seed from tubers which have thus sprouted into a secondary tuber-production is most indifferent, and the produce is certain to be weak. If these tubers were, in addition, diseased, or if the disease had been introduced in other seed, planted contiguously, then they would be particularly prone to take it severely. When disease broke out in Lower Bengal in 1900, the Naini Tal seed which is so largely grown there, fell an easy prey to it.

Disease not severe in Kumaun.

20. On the whole then, though **Phytophthora** undoubtedly exists in Kumaun, still it is evident that general disease from it does not occur; and there is nothing to show that Naini Tal seed can be accused any more than seed from any other infected area of first conveying the disease to Bengal. It is merely clear that the Naini Tal produce was less resistant to the disease than other varieties.

In Kumharsain State.

21. Enquiry further west has led to the detection of **Phytophthora** disease in the Native State of Kumharsain, north of Simla. Specimens of a disease stated to exist in this locality were received by me through the Director, Department of Land Records and Agriculture, Panjáb, in September 1902, and showed abundant fructifications of the fungus on the under surface of some of the leaves. The blight is said to occur every second or third year and is noticeable in years when there is heavy rainfall. The external signs of it are similar to those of a disease reported to be prevalent this year at Phágu, Keonthal State. It is believed that this disease attacks the crops every year in Keonthal in the month of August. The first signs of it are that the leaves of the young plants turn yellow and begin to dry, and by the end of August rot and fall away. When the potatoes are dug up it is found that the roots in the majority of cases are rotten and the potatoes themselves discoloured and, in not a few cases, quite rotten and inedible. I was unable to find **Phytophthora** in the specimens received from Phágu, but have little doubt it was present in the crop from which the specimens were taken. As a matter of fact it is not easy to get good specimens from such a locality. Since the fungus appears chiefly on the leaves, and these rapidly drop off, plants in the early stages alone are satisfactory for examination. As far as I could judge from the sample received only quite dead stalks were gathered. Cultures tried from the blackened tubers gave negative results probably owing to the exposure to high temperature on the journey through the Panjáb having destroyed the vitality of the fungus. I am not disposed to attach great importance to the negative result of examination of the specimens from Phágu, while the positive proof got from the similar disease in Kumharsain, by the detection of **Phytophthora** on the leaves, makes it probable that at Keonthal, as at Kumharsain, the disease is established.

Identification of the disease.

In Keonthal State.

Description of attack.

Phytophthora not found in Keonthal specimens.

Probably exists.

SOLANUM tuberosum. Potato Diseases of India.

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First appearance in the plains.

22. In the great area between the Himalayas on the north and the Nilgiris on the south, potato disease due to **Phytophthora** was reported for the first time last year. In a letter from the Officiating Director of Land Records and Agriculture, Bengal, to the Superintendent, Royal Botanic Garden, Calcutta, dated 15th February 1902, it was stated that a serious potato blight had broken out in some parts of the Hooghly district. Specimens were received by me for examination through the Department of Land Records and Agriculture, and also from the Assistant Reporter on Economic Products. They were found to be badly attacked by **Phytophthora.**

Hooghly district.

Local enquiry.

23. The outbreak was investigated locally by **Babu N. C. Choudhury**, a Travelling Overseer of the Department of Land Records and Agriculture, Bengal, who afterwards visited Darjeeling where the first potato crop had also been seriously diseased. A copy of his report was kindly furnished me by the Officiating Director, Land Records and Agriculture. The following particulars are taken from it.

Confined to Hooghly.

24. The disease was reported on the 30th January 1902, by the Collector of Hoogly, from thana Singur in the Sub-division of Serampur. **Babu Choudhury** found it confined to the Hooghly district, which is the most important potato-growing district in Lower Bengal. Burdwan district, the next most important in regard to potato cultivation, and 24-Parganas, where cultivation is only nominal, were unaffected.

Spreading from a centre.

25. The blight first appeared in the Singur thana, and spread to the surrounding villages in thana Haripal to the west, Dhaniakhali to the north-west and Chanditolla to the south. Thanas Jagatballavpur and Amta in the Howrah Sub-division and Tarakessur to the west of Haripal were also slightly affected. Generally the greater the distance from thana Singur the less the disease. Mogra to the north of Dhaniakhali was free from it.

Estimate of loss.

26. It was first observed in 1899-1900 in a few fields of thanas Singur and Chanditolla. The damage was slight. The next year, 1900-1901, it was worse and was present in thana Haripal. Last year it had still further extended and was extremely virulent. It was estimated that the loss was in many cases 50 to 75 per cent, only 15 to 30 maunds of indifferent potatoes being got, instead of 60 or 80, per bigha ($3\frac{1}{3}\frac{1}{0}$ bighas = 1 acre). Late sown potatoes were most affected, those which ripen in the beginning of January escaping.

Varieties affected.

Naini Tal imported seed, which ripens in February, suffered most, and these potatoes occupy a larger area in Hooghly district than all the other varieties put together. As usual, mention is made of excessive or unseasonable rain as favouring the disease, it having fallen in November 1900, December 1901, and November

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Conditions favouring disease.

1902. Probably a more potent factor is the excessive irrigation described as in vogue in thana Singur. The cultivators here irrigate at intervals of about 6 days so that the soil is kept saturated. This, as we shall see below, is most unwise when disease is to be feared. Mention is also made of the cultivators' belief that the disease is due to the western winds, which, as Babu Choudhury suggests, may have a favouring effect by reducing the cold at the growing season. Moist, foggy weather such as is common in Calcutta at this season is known to be one of the most frequent precursors of the disease in other countries, but no mention is made of it in Hooghly, and I do not know if it accompanies the west winds spoken of.

Disease previously unknown.

A former disease.

27. Before 1900 the disease was unknown to the cultivators. Another disease which in former years did much damage, was called by them *Dhasa*, a term also applied by some to the new disease. This former disease appears to have been that described below as "Bangle blight," the cause of the worst damage to potatoes in Bombay Presidency.

Vernacular names.

28. Various names have been given in the vernacular to the **Phytophthora** disease. In Singur it is known as "Dhasa" or "Marka" as the plant rots or dies. In thana Chanditolla it is known as "Tipi" as its first sign is a spot. In Nalikul it is called "Topadhora." It is sometimes called "Marmaria" as the plants are supposed to fall down as rapidly as trees are blown down by a storm.

Varieties grown in Lower Bengal.

29. It would appear from Babu Choudhury's report that the varieties of potatoes grown in Lower Bengal are chiefly the following:—

Patna commanding the lowest price, country, Naini Tal, Umballa and Bombay. Naini Tal, Patna and country which are chiefly grown in Hooghly district were all similarly affected with the disease, but, as mentioned already, the Naini Tal were the worst.

Cultivation.

30. As a rule the best fields of the cultivator are cropped year after year with potatoes. Those crops which were grown in fields selected for the first time were less attacked. The potato fields in the Hooghly district are manured with 15 to 30 maunds of castor cake and about 150 maunds of rotten cowdung per acre.

Disease not known elsewhere in India.

31. **Phytophthora** disease does not appear to occur elsewhere in the Plains or Peninsular area of India. Mr. Mollison, Inspector General of Agriculture, does not believe it exists in Bombay, where the second of the two serious Potato diseases of India is chiefly found. In the Central Provinces potato cultivation is small and disease is apparently absent. From Burma two samples of diseased tubers have been received. One, of imported Darjeeling seed, from the Southern Shan States through the Officiating Reporter of Economic Products, Calcutta, and the other from Sima, through the Director, Department of Land Records and Agriculture,

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Burma. Both showed discolourations in the interior, but I could not detect the presence of **Phytophthora.** The tubers are being grown for further examination.

32. It would thus appear that with the exception of the recent outbreak in Lower Bengal, the Plains of India and the Deccan are free from the disease.

Difficult to understand the invasion of the plains.

33. It is not easy to understand how the fungus can ever have become established on the Plains of Bengal. The gradual extension from a centre at Singur, lasting now over three years, makes it, unfortunately, probable that the fungus has in some way managed to live through the hot season in the infected locality, and has not been introduced afresh each year. Such an occurrence is, so far as I am aware, unprecedented, as it seems to have been assumed that exposure to such a temperature as prevails in Bengal for several months of the year is fatal to the fungus. Jensen states, as a result of prolonged experiments, that exposure of the tubers to a dry heat of 100° to 105°F. for four or five hours is sufficient to thoroughly disinfect diseased ones. Later figures give 104°F. as the lower figure. The upper layers of the soil in Bengal are subjected to a much greater heat than this every year, and if a perennial mycelium, such as is found in diseased tubers, were to occur in the soil, it should be quickly killed off. It is possible that the cultivators reserve a portion of their crop each year for seed in addition to importing fresh seed, and this local stock may be stored in such a way as to escape the high temperatures of the hot season. In this way the mycelium could persist from year to year in the tubers, and pass in the growing season to infect an ever-widening area. But it seems clear that for the future no part of India can be held safe from invasion, and it will be surprising indeed if the blight does not extend into every province for the country.

Estimate of damage caused by *Phytophthora.*

34. ***Losses from the disease.***—It is impossible in most cases to form any estimate of losses caused by potato disease in India. The following figures from Bulletin No. 5 of the Assam Agricultural Department show that a great disease in exportation of potatoes from that Province has occurred since the blight appeared. The figures show the exports *viâ* the Brahmaputra and Surma Valleys taken together :—

Exports from Assam.

Year.	Maunds.
1884-85	103,536
1885-86	114,739
1886-87	109,502
1887-88	42,374
1888-89	26,405
1894-95	12,301
1895-96	8,296
1896-97	16,726

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35. It is, however, pointed out in the Bulletin, that it is uncertain how far the great decrease in exports since 1885-86 represents a reduction of the area under potato cultivation in the district, since it has coincided with the development of cultivation in Lower Bengal, and also since Kumaun potatoes have largely replaced Khasi varieties for seed within the last few years. At the same time internal consumption, especially on tea gardens, has increased. Still the consensus of opinion is that the area has greatly diminished since the appearance of **Phytophthora infestans** in 1885. The Khasia cultivators look with less favour on potatoes now than formerly, and it is not surprising that they have to a great extent abandoned its cultivation for other crops. The average yield is said to be only five-fold for the first crop and two-fold for the second. The product is of bad quality, and blackened tubers (as I can personally testify) are so common that it is rare to get a dish that does not contain several. Much of this deterioration is no doubt due to the disease.

Yield and quality.

36. In Hooghly, **Babu Choudhury** made a painstaking effort to estimate the loss caused by the disease last year. The following table drawn up by him shows the rise in price consequent on the appearance of the disease in potatoes of the Patna variety sold for the Calcutta market:—

Loss in Hooghly.

Price for Calcutta market.

	₹	a.	p.	
1898	1	6	0	per maund.
1899	1	4	0	„
1900	1	4	0	„
1901	2	0	0	„
1902	2	0	0	„

37. That the price in 1902 was not higher than in 1901 is considered by **Babu Choudhury** to be possibly due to a great diminution of exports from Calcutta to Rangoon and Chittagong, a fall of from 16,000 maunds per month in 1901 to 5,500 maunds per month in 1902.

Exports from Hooghly.

38. The diminution in yield appears to have been enormous. In 1900, 206,400 maunds were estimated as available for export from the Hooghly district; in 1901, 275,000 maunds were so available, and in 1902, 160,000 maunds only, a drop of 41·8 per cent. from the previous year. In many cases, **Babu Choudhury** remarks, the cultivators would not be able to recover the cost of either manuring or seed.

External signs.

39. *Symptoms of the disease.*—The external signs of the disease are not always the same, depending to some extent in the later stages on the weather, especially the degree of humidity, and on the association of certain bacteria, chiefly of the butyric acid group. In all cases the first sign of the disease is the appearance of small brown

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patches on the leaves. These are found everywhere both at the edges and over the whole surface, and increase in size rapidly, coalescing with neighbouring patches. As the edges are attacked the leaves often curl up. Like the leaves, the petioles and stem are often covered with brown patches. When the air is humid, extension

Rotting.

of these patches is very rapid, and a general softening or rot caused by a crowd of other organisms which follow in the train of the **Phytophthora**, occurs over the attacked areas of the plant. The extent to which this progresses varies very much. In some cases the leaves alone fall leaving the stalks standing for a little time quite bare. In others leaves and stalks fall over together in a rotten pulp.

Odour.

The odour which is often so marked in these last cases and which can be smelt for miles in Ireland in a bad year, is chiefly due to the butyric acid bacteria accompanying the rot.

Shrivelling of leaves.

40. In other cases, especially mentioned by French writers, it would appear that the brown patches dry up causing the leaves to contract and become deformed. This is probably the natural action of the fungus unaccompanied by any putrefactive organisms.

Organs of dissemination.

41. On the under surface of the leaves, the organs by which the fungus is disseminated soon appear. Their position is indicated by a sort of white haze visible on turning up a leaf at the margin of the brown patches. This haze is formed of a multitude of more or

Spores.

less erect filaments bearing spores or organs of multiplication, which can sometimes be seen in dry weather as a fine white powder mingled with the filaments. They spring from the main body or "mycelium," of the fungus, which consists of numbers of threads or "hyphæ" buried in the substance of the leaf and pushing everywhere between the cells.

42. These threads, erect filaments, and organs of reproduction, which form all that we know of the fungus **Phytophthora**, merit a fuller description.

Microscopical characters.

43. In a thin section of a leaf taken just outside one of the brown patches, colourless hyphæ of the fungus can be seen under the microscope, squeezing their way between the green cells of the leaf tissues. They do not enter these cells as a rule, being apparently able to absorb the nutrient juices across the cell wall. In rare cases, however, short branches of the fungus perforate the walls and enter the cells to act as suckers, organs which are common in the other fungi allied to **Phytophthora**. But whether suckers are formed or not, the result is the same. The food material present within the cell is taken up by the parasite which at the same time probably excretes some poisonous substance capable of destroying the living protoplasm. Consequently death occurs with great rapidity. Where the fungus touches a wall the latter browns, and the

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brown colour extends along the walls to parts not yet reached by the threads. In the tubers, as is well known, these brown spots are usually strongly developed, but it must not be forgotten that many other causes induce a similar discolouration. As the cells are killed, the fungus continues its growth, dying out behind as it spreads into tissues as yet healthy and kills them in their turn. It is not able to live on dead matter, requiring as food the living substances of the potato or of a few other allied plants, such as the tomato, belonging to the SOLANACEÆ, and some of the SCROPHALARIACEÆ. When the under surface of the leaf is reached, tufts of aerial filaments emerge through the stomata or air-openings, which are found only in this locality. Some of these filaments are represented in fig. 1. These are the conidiophores or spore-bearing structures. As may be seen they are branched in a tree-like manner and often provided with little enlargements which give them a beady appearance towards the apex. At the tip of the main filament and of each of its branches a conidium or spore is developed. This is cut off by a septum formed a little way below its base, and, as the filament still continues to grow, the spore and its minute stalk are pushed over to one side and usually fall off. Ten or more spores may thus be formed during the growth of the filament, and the little enlargements just mentioned each indicate a place where a spore has existed and has fallen off. To represent the filaments as being provided with walls or septa at each of these enlargements as is done in some textbooks is erroneous. This portion of the filament is rarely septate, but the lower part of the aerial threads, and the hyphæ within the leaf, are sometimes divided up by walls placed at irregular intervals. These are never formed in the parts of the fungus which are still growing and are full of protoplasm, but serve to cut off growing parts from those which have finished growth and have been depleted of their contents.

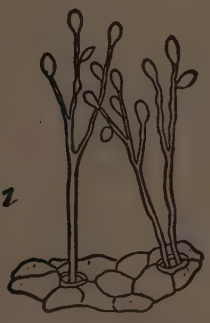

Figure 1.—**Phytophthora infestans** *de Bary.*—Portion of the epidermis of the lower surface of the leaf with two stomata through which project conidiophores bearing conidia. Magnified 100 djameters (after Percival).

44. *Dissemination of the disease.*—The spores which are thus thrown off from the tips of the tree-like conidiophores are the means by which the fungus is disseminated from leaf to leaf, and from plant to plant. Myriads of them are produced on the first infected plants in favourable weather. From these they are spread chiefly

Dissemination by spores.

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by the agency of the wind. We have only to consider the size and weight of the conidia, which measure about $\frac{1}{800}$ of an inch in their longest diameter, to realise how readily they can be blown about like powder. Each spore can reproduce the disease provided that it falls on a potato plant, and is supplied with the requisite moisture to allow of germination.

Germination of spores.

45. A **Phytophthora** spore can germinate in either of three ways. Usually on falling into a drop of water (rain or dew) the contents of the spore divide up into a number of parts (from six to sixteen); then the tip of the spore dissolves and each of the parts is expelled rapidly into the water (fig. 3). Here it assumes the shape shown in fig. 4, and two cilia or swimming organs are put out. By means of these, the little particles, now known as zoospores, are capable of moving about for a quarter of an hour or more in the water. Then they come to rest and each puts out a germ-tube which becomes a fungus filament. This process may occur for as much as three weeks after

Figure 2.—**Phytophthora infestans.**—Ripe sporangium showing the zoospore origins already marked off. Magnified 390 diameters (after De Bary).
Figure 3.—Discharge of zoospores.—Magnified 380 diameters.
Figure 4.—Two zoospores in the active state. Magnified 380 diameters.
Figure 5.—Zoospores come to rest and beginning to germinate. Magnified 390 diameters (after de Bary).
Figure 6.—A conidium germinating directly by a germ tube. Magnified 380 diameters.

the maturation of the spores if the latter have not completely dried up. If the ripe spore has fallen on to the film of rain or dew which covers the surfaces of leaves and stalks in the moist weather which almost invariably accompanies bad outbreaks of the disease, the swimming spores go off in all directions, and form so many centres of infection. For the filament emanating from each of the zoospores has the power to penetrate the substance of the leaf or stalk in search of the food on which alone it can live. Once within the tissues

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it immediately begins its work of destruction, and growing vigorously soon reproduces the branched mass of threads above described in the interior of the plant. These swimming spores form a means of dissemination of the fungus apart from the air-borne conidia, since diseased and healthy plants are often in actual contact with each other in thickly sown fields, so that passage from plant to plant through the water becomes possible.

46. A second mode of germination is often found in which the conidium on falling on a moist surface puts out, itself, a germ-tube, instead of giving rise to a number of zoospores. This tube grows for a while and forms a new spore at its apex, which falls off in its turn and gives rise to zoospores or to a germ-tube.

47. A third mode is also found in which the spore gives rise, as in the last case, to a germ-tube, but this directly enters the substance of the potato plant without waiting to form a secondary spore.

48. The first of these three methods of germination usually occurs in spores which fall into water shortly after their maturation. The last two are found chiefly in older spores.

Spores can infect all parts.

49. Though the spores are only formed on the under surfaces of the leaves, their germ-tubes have the power to penetrate any part of the potato plant even the tubers, across their tough skins.

Infection of tubers.

50. It is usually held that infection by spores which have been washed through the soil into contact with the tubers, is the means by which the latter become diseased. Some consider, however, that extension of the threads takes place down inside the stem, and that they reach the tubers in this manner. Experiments seem to show that the former is by far the commoner way and that if the spores can be prevented from entering the soil the tubers will usually escape. Thus Mr. Carroll of the Glasnevin Model Farm, Dublin, succeeded by covering the ground under diseased plants with a layer of cotton wool in preserving the tubers from disease most successfully. Jensen's treatment of the blight is in part based on this belief.

Dormant mycelium in tubers.

51. When the tubers become infected they are sometimes destroyed in the same way as the leaves, with the difference that as bacteria are more abundant in the soil, so rotting is more rapid. Very often, however, the fungus threads pass into a dormant condition without doing any great injury. Tubers containing dormant hyphæ show in their interior brown spots, due, as already said, to the power possessed by the growing fungus to turn brown the cells with which it comes into contact. On storage these tubers are often destroyed by rot. This is probably due to a weakened vitality from the presence of the fungus, which allows of the rotting bacteria to become established and to destroy the tuber, rather than to any direct growth of **Phytophthora** itself. It unfortunately happens, however,

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that tubers, to all appearance externally sound, may last through the year and be available for planting, though containing within them these dormant filaments. On germination, the fungus re-starts into life and growing up the newly-formed stem reproduces the disease.

Sexual or resting spores.

52. Most of the near allies of **Phytophthora**, amongst the fungi, are provided with another means than the formation of dormant, enduring, filaments, of persisting from year to year. This is the production of sexual spores which on fertilisation are capable as oospores, egg-spores or resting spores of living through long periods and of withstanding great variations of temperatures and dryness.

Not known in *Phytophthora infestans.*

For **Phytophthora infestans** these are not known, and if formed at all they must be extremely rare. An English botanist **Worthington G. Smith** claimed to have found them in 1875, but his evidence was inconclusive. **De Bary**, the great German mycologist, showed that part of **Smith's** specimens were produced by an allied fungus, **Pythium vexans**, and part were identical with a fungus described by **Montaigne** as **Artotrogus hydnosporus** which **De Bary** showed to be also a **Pythium** and called **Pythium Artotrogus.** In the tubers which I received from Hooghly, last year, I found considerable quantities of this last fungus, and was able to obtain it in culture free from the **Phytophthora.** The character of the threads of the two fungi is quite distinct and there can be no question of their being different things. The curious thing is that **Pythium Artotrogus** is usually found in conjunction with **Phytophthora infestans** and **De Bary** has suggested that it may be a parasite on it. It is, however, capable of growth apart from **Phytophthora.**

Two methods of infection known.

53. We see then that the fungus of potato disease has spread from continent to continent, and can persist from season to season, by means of dormant threads within the tubers, threads which can be killed by a temperature exceeding 104° F., and that each season it is disseminated from plants which have sprung from diseased seed by spores produced on their leaves. Also that these spores are delicate things, and at most can live for a few weeks and that only if preserved from drying. This knowledge enables us to indicate the lines on which treatment may be successful in checking the disease.

Principles of treatment.

54. *Treatment of the disease.*—Treatment may be directed on the one hand to securing that tubers containing living fungus are not utilised for seed, and on the other to preventing the spores of **Phytophthora**, should they fall on the leaves of healthy plants, from germinating and thereby infecting them with the disease, or should they fall on the soil from passing down to the tubers. It may be said at once that no method of curing the disease once it appears on a plant has been devised, and that no potato has been produced as yet which is disease-proof.

Direct.

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Indirect.

55. Besides direct treatment of this nature, aimed at the fungus, it is not less important to strive to improve the resistant powers of the potato plant by good cultivation and by the constant introduction of new varieties raised from seed.

The question of seed.

56. To secure the first of these requisites that tubers containing living fungus are not utilised for seed is unfortunately not possible in every case. Much may, however, be done to minimise the danger. Thus it must be self-evident that it is madness to use as seed, tubers which have been procured from a district known to have severely suffered from the disease in the last season. Thus, if seed from Darjeeling for instance, where the disease was severe last year, be imported into any other district for this season's sowings, it is natural to expect that the potential danger of a bad outbreak is considerable; for a number of tubers will be diseased, and all that is wanted is a suitable range of temperature, moisture, etc., to induce a large development of **Phytophthora**. If, however, disease has not been virulent for the last few years, the number of dangerous tubers will be proportionately lessened. Again, it is evidently a safer practice to use cut sets only, in localities liable to disease, if the seed be of a suspected quality. Unfortunately practical experience goes to show that small cut sets give poorer returns than the planting of whole tubers. But it should not be difficult in particular districts to balance the financial objections to the two practices, and to arrive at a decision as to whether it be better to obtain a larger outturn at the risk of inducing severe disease, or a smaller crop in which the danger from disease is lessened. I do not think there can be any doubt that it would pay the cultivators in Hooghly, for instance, for the current year, to cut all sets, planting only those which are unblackened, since, as we have seen, there is great danger in that district if climatic conditions be favourable, of severe disease.

Cutting the sets.

Jensen's hot water treatment.

57. A method has been devised by **Jensen** of Copenhagen of sterilising suspected seed tubers. He recommends that they be placed in vessels plunged into water at a temperature of 104° to 120°F. for four or five hours, a treatment, which he states as a result of numerous experiments, ensures the destruction of the fungus without in any way injuring the germination of the seed. Chiefly, it would seem, on account of the excellent results got by the use of Bordeaux mixture, which will be treated of below, this method of **Jensen** has not been much used. It might be worth a trial in districts where excessive rainfall renders the use of Bordeaux mixture both expensive and of doubtful efficacy by washing the mixture off the leaves as fast as it is applied. To be successful, however, it must be done generally throughout a district, if the potato fields lie at all closely to gether. Otherwise each untreated field will serve as

PHYTOPHTHORA INFESTANS. Bordeaux mixture.

a focus, from which spores can be blown to all the fields in the neighbourhood.

58. To prevent the spread of **Phytophthora**, by means of spores, from plant to plant, only one method at the present day is considered to hold out a fair prospect of success. It is the spraying of the crop with Bordeaux mixture, first recommended by Prillieux and used by Jouet in France, in 1885. An exhaustive series of experiments was instituted by the Board of Agriculture in 1892 and 1893 throughout the British Isles and supplemented by enquiries made in the colonies and in other countries. The results were quite conclusive as to the value of the treatment when carefully carried out; and this has been the experience wherever the remedy has had a fair trial. Not alone does spraying check the spread of disease, but it also increases the yield of potatoes per acre by some action not yet quite understood but probably by preserving the foliage green, and in a condition of vigour for carbon assimilation, longer than would otherwise be the case. This increased yield in most cases covers the cost of the application even when no disease has appeared.

Nature of the mixture.

59. Bordeaux mixture (bouillie bordelaise) is a mixture of sulphate of copper and lime in certain proportions which causes the formation of copper compounds not yet clearly known. These are thrown down in the form of a fine precipitate, probably containing basic copper sulphate and copper hydrate. A clear liquid remains above free from copper.

Preparation of the mixture.

60. To prepare 50 gallons of this mixture the following directions may be useful. Weigh out 6 lbs. copper sulphate, break to powder and dissolve in 25 gallons of cold water by suspending in a piece of gunny sacking in the water. The latter must not be contained in a metal vessel but in a barrel or big earthenware pot. In another vessel weigh out 4 lbs. of fresh quicklime. Slake this gradually till it falls to powder and then add water up to 25 gallons. Let cool. Then add to the copper sulphate solution through a sieve so as to retain any lumps which would clog the sprayer, stirring vigorously with a wooden stirrer. A thick bluish liquid at first results, which on standing throws down a bluish precipitate leaving the upper part of the liquid clear. This clear liquid should turn blue red litmus paper, and should not give rise to a reddish precipitate on adding a few drops of ferrocyanide of potassium. If this precipitate appears some copper still remains in solution and may be injurious to the leaves. More lime should therefore be added. A convenient way of determining if copper remains in solution is to plunge a steel knife into the liquid, when, if a coating of copper is formed on the knife, more lime should be added. The mixture is now ready for use. It may be best applied

Practical considerations.

PHYTOPHTHORA INFES. TANS.

by means of an Eclair Sprayer with the Vermorel nozzle,* the mixture being well stirred before use. Too much lime clogs the nozzle. Air-slaked lime may cause damage to the foliage. Application during the heat of the day may also cause injury. Two applications should suffice, one just before the disease usually makes its appearance and the other as soon as the first signs of it have appeared. The spraying should be thorough. At first it was thought necessary to spray the under surfaces of the leaves—a difficult matter,—but it has been seen above that infection can, and usually does, occur through the upper surfaces. It is here naturally that the great proportion of air-borne spores falls. About 150 gallons per acre is usually found necessary for each application. More than 200 gallons should not be required. The cost is not large. European experience gives about 7 or 8 shillings per acre as an average for each application. Many prefer to use a mixture of twice the strength of that above. As many as six light sprayings are sometimes given in the United States at a cost of about 5*s.* per application. Sulphate of copper costs about 3*d.* to 4½*d.* per lb. in Europe. A Calcutta firm informs me that it can be supplied in Calcutta at R20 per cwt, or less than 3 annas per lb.

Quantity required.

Cost.

61. In Darjeeling, Assam, and other districts of India where the rainfall is excessive, Bordeaux mixture may fail through being washed off the leaves. This appears to have occurred at the Upper Shillong Farm, Assam, where the treatment has not been a success. In such cases a method of increasing the adhesive properties of the mixture adopted with good results in other countries may prevent this undesirable event. This is the addition of treacle or molasses (about 5 lbs. in preparing fifty gallons as above), to the lime wash before adding it to the copper solution. The treacle should be diluted with some water so as to make it of a thin consistency.

A cause of failure.

Its prevention.

62. The use of this treatment renders the tubers in no way dangerous for consumption; for analyses, often repeated, show that none of the copper reaches the tubers. Sir Charles Cameron, Medical Officer of Health, for Dublin, found, however, that copper is taken up by the leaves and stems of sprayed plants though he also got no trace of it in the tubers.

Treatment safe.

63. The result of a thorough spraying is to coat the leaves and stems of the crop with a fine film containing the copper salts. On the spores falling into this their germination is prevented and infection of the plant does not occur. As may be seen this treatment is preventative not curative and it is usually considered that once the

Result of treatment.

* This is European experience. I believe that in India a simple syringe costing about a rupee would better suit the conditions of the cultivator to whom time and labour are of no particular account, while initial expenditure is.

PHYTOPHTHORA INFESTANS. Experiments required in each district.

filaments of the fungus are growing vigorously within the substance of the leaves the mixture exercises little or no influence on their growth. Experiments are required in each district to determine the best means of securing the desired effect. The number of sprayings and the strength of the solution required depend to some extent on the climate, especially the rainfall.

Jensen's "protective moulding."

64. To prevent spores reaching the tubers by being washed into the soil, Jensen, of Copenhagen, instituted the system known as "protective moulding." His experiments indicated that the filtering effect of the soil in checking the passage of spores was considerable and he therefore recommended banking up the earth round the stems so that the uppermost tubers are covered with about 5 inches of soil. This should not be done until the disease usually is expected to appear, or at the first signs of it. By this means it is hoped that the spores will fail to penetrate to the tubers. The system has not found great favour, since experience goes to show that, though the number of diseased tubers is lessened, still the yield is smaller than in unbanked crops

Precautions in handling crop.

65. Some other precautions may be observed in handling the crop when disease occurs. The tubers should not be lifted for some time after the complete dying down of the stalks, or there will be a danger of infecting sound tubers by living spores from the leaves or soil. A less satisfactory way of avoiding late infection is by burning all débris on the ground. Some spores in the soil will, however, certainly escape the latter, and may convey the disease if the tubers are lifted immediately. At least a week should be allowed to elapse before stirring the soil, and in moist soils three weeks may be necessary, since, as already said, spores have been kept alive for this length of time. In storing tubers intended for seed the following season they should be kept in a dry well-aerated place. It has been found that spores are sometimes produced on the surface of diseased tubers in storage and these are readily conveyed to adjacent sound ones. The presence of moisture in these cases permits the spores to germinate, and the disease continues to spread from tuber to tuber.

Power of resistance to disease.

66. Besides the above treatments, all directed against the fungus, long experience has shown that there are other precautions quite as necessary in preserving the crop from disease. They may be summed up in the phrase "keep up the resistance to disease of the potato plant itself." For long it was believed possible to produce a disease-proof variety of potato. It is now, however, fairly evident that all varieties become liable in time, though some are less so than others. These latter, disease-resisting varieties, lose the property, if neglected, in a few years, and constant attention is required to keep them up to the standard by selection and by crossing with other

varieties. This work, carried out by all the large nurserymen in Europe, is quite unknown in India. It is probable that the experience noted already of English potatoes in Darjeeling, and Naini Tal potatoes in Assam, having at first succeeded in withstanding the disease while afterwards succumbing, indicated the possession of this power to some extent; and it might have been possible by judicious selection, or by raising seed from the new varieties, to have established a strain resistant to a greater degree than the indigenous. Importing new varieties unless constantly practised cannot be expected to lead to any permanent diminution of the disease, but importation combined with selection may do so. The introduction of varieties grown from seed, not from tubers, from time to time, has been found essential in other parts of the world where disease prevails, since continued reproduction by sets tends to weaken the resisting powers of most plants. It is an undertaking that cannot be too strongly urged for India, where many of the native varieties are extremely poor, and the results of seed raising, with selection of the best plants only for future use, would probably give very rapid improvement.

PHYTOPHTHORA INFESTANS.

Weakening of resistance.

Continued reproduction by sets.

67. The raising of two crops a year on the same land continuously is bound to give a weak crop unable to resist disease. It is not likely, however, to be abandoned. Besides being agriculturally unsound, it often leads to the first crop being raised when immature and thereby greatly increases the danger of late infection of the tubers.

Excessive cropping.

68. Excessive irrigation on badly drained land is also unwise. **Phytophthora** thrives best in moisture, and in moist soils the danger of the spores reaching the tubers is likely to be accentuated. An addition of lime to the fields may sometimes be useful. This is especially to be recommended where richly nitrogenous manures are employed. Nitrogen has been found to lower the resistance to disease somewhat, and this effect can be counteracted by the use of lime.

Excessive irrigation.

Addition of Lime.

69. It must be said that there is need of some accurate observations and experimental field work before European experience can be applied to Indian conditions with a maximum of success. It is possible that the excessive rainfall of some of the Hill districts, the great seasonable variations of temperature and moisture, and the difference in cultivation may lead to a modification of some of the methods found satisfactory in Europe. But the first requisite is a clear idea of the cause and mode of spreading of the disease, and of the conditions in which the fungus finds its greatest capacity for mischief, and these I have endeavoured to give. The knowledge thus acquired, intelligently used, should render possible the application of remedial measures to particular outbreaks with a fair prospect of success.

Need for observation and experiment.

"BANGLE" BLIGHT.

CHAPTER II.

"Bangle" blight.

First account of Bangle blight.

70. *History.*—A disease, known to the native cultivators by the name of "bangdi" disease, from the appearance of a dark ring visible on section in the substance of the potato, was brought to the notice of the Department of Land Records and Agriculture, Bombay, in 1891, (see "A Note on the Potato disease prevalent in the Poona district and elsewhere" by **E. L. Cappel**, Director of the Department of Land Records and Agriculture, Bombay, June 1892). It affected the crop of the Khed and Junnar Talukas, whence the greater part of the supply for the Poona and Bombay markets is drawn. Shortly afterwards it was reported to occur elsewhere in the Poona district, and in Gujarat and Mahableshwar. It was stated to have first appeared some three or four years earlier. By 1893 it had been found very widely distributed in India: at Bangalore, in the Nilgiris, in Bengal and all through Bombay Presidency. In the Nilgiris we have seen that **Phytophthora** disease has been long established. The occurrence of a second blight here does not seem to have been fully realised, and it is probable that no distinction is made between the ravages of the two pests. In Bengal **Babu Choudhury** found, while investigating the **Phytophthora** out-break, that the memory of a previous blight remained amongst the cultivators. It was spoken of as "Dhasa" a name also applied by some to the new disease. The two affections were, however, recognised as being distinct, and it is probable that the old Dhasa was "Bangle blight" which **Mr. Cappel** states extended to Bengal ("Second Note on the Potato disease prevalent in the Poona district and in other parts of India," 1893). It would seem to have now disappeared from that Presidency while still prevalent in Bombay. In the extent of its ravages it is probably second only to the **Phytophthora** in India.

Area affected.

Probably next to *Phytophthora* in destructiveness.

Dr. Cunningham's investigations.

71. In 1892 specimens of the disease were submitted by **Mr. Mollison**, then Superintendent of Government Farms, Bombay, to **Dr. Cunningham**, Special Assistant to the Sanitary Commissioner with the Government of India, a well-known authority on fungus diseases. His investigations were published in the Scientific Memoirs by Medical Officers of the Army of India, Part X, 1897. The leaves and upper part of the stalks were found by him to be normal, except in so much that they were wilted and showed a fading of the green colour. The base of the stalk, however, was discoloured, and in section brown spots were seen corresponding to the vascular bundles. On microscopic examination the vessels were found choked

"BANGLE" BLIGHT.

with the mycelium and minute sclerotia* of a fungus. The latter appeared to be strictly confined to the wood, being present in the interior of the spiral vessels, the wood cells and, especially, the great pitted ducts. It was in these ducts that the sclerotia were found. The upper part of the stem, the roots and the tubers were free from filaments of the parasite. Even the blackened area of the "ring" in the latter did not show its presence. In the following year further specimens were examined by **Dr. Cunningham**, and some modifications were found necessary in the above description. Thus the blackening of the stem was less marked, sclerotia were not found, and scattered filaments of a fungus permeated all the tissues, being still most abundant in the spiral vessels.

Rapid wilting.

72. *Symptoms of the disease.*—The first symptom externally of the disease is a "wilting" of the green top, which occurs suddenly. A plant may look quite well one day, show signs of fading the next and droop on the third day. This does not occur generally throughout a field, but scattered plants everywhere are seen withering in the midst of green ones. The difference between this and the **Phytophthora** disease, which attacks field by field rather than plant by plant, is striking. The tuber is arrested in growth, so that the crop where disease is severe is generally poor and composed of small tubers; many are rotten when dug and others rot in quantity in storage. The disease appears only as the crop approaches maturity; and at first, even when the discolouration of the stalk just under the surface of the soil is apparent, the blackened ring is not visible in the tubers. Infection from plant to plant, so that the disease radiates from the first attacked plants, was not observed to occur to any great extent. The symptoms of the disease are considered by **Dr. Cunningham** to be due to obstruction of the free passage of water up the stem, by fungus filaments in the vessels. The disease is thus typically a "Wilt disease" of which many examples occur, both in India and elsewhere, amongst cultivated crops.

Not universal.

Only appears at maturity.

Tubers late affected.

Spores not found.

73. It does not appear that cultures of the fungus were obtained by **Dr. Cunningham**, and it remains doubtful, therefore, whether it is capable of dissemination by spores. Spores were not found in nature. **Dr. Cunningham** points out, however, that the characters of the disease and the nature of the fungus, especially the production of sclerotia within the vessels, are typical of certain Ascomycetous fungi such as **Sclerotinia (Peziza)** or its allies. In these the production of spores is not common, being in some species unknown, but the fungus persists from year to year by means of its sclerotia,

Dissemination by sclerotia.

* Sclerotia are merely felted masses of the fungus threads which form bodies usually of a tough horny nature capable of preserving their vitality for a long time. They are not spores but are usually much larger bodies.

"BANGLE" BLIGHT.

which, like resting spores or the dormant mycelium of **Phytophthora**, can withstand variations of moisture and temperature, waking to life again when conditions become favourable.

Field work of the Bombay Department.

74. *Field experiments.*—In 1892 and 1893 extensive field experiments were carried out by the Department of Land Records and Agriculture, Bombay, for the purpose of testing the extent to which different varieties of potato suffer from the disease, and the means by which it might be combated. These did not bear out Dr. Cunningham's opinions in one respect, namely, that the fungus does not reach the tubers, since they pointed unmistakeably to seed infection as one of the ways in which the disease is propagated. Thus, although as a general rule, new potato land gave sounder crops than old, still in Khandesh, where potatoes were not previously grown, a field at the Government Farm which had never been under potatoes before, bore a diseased crop when sown with potatoes marked by the black "ring" of the disease. Infection from without was hardly likely here. "No

Seed infection occurs.

conclusion has been more clearly pointed out by the experiments and observations conducted in the field during the past two years than that the disease is propagated from the seed as well as from the soil, and that if anything the first source of infection is the more dangerous and common" (Cappel, *l.c.*, 2nd note).

Predisposing causes.

75. Amongst the conclusions come to as a result of field experiments in Bombay were the following.

A predisposition to the pest is probably to be found as a result of exhaustion of the soil and of the stock, owing to overcultivation.

Over-cropping.

"The crop is so profitable that it is grown year after year on the same land, and the unwillingness of the cultivator to exchange it for less valuable produce, even when disease is rife, forms one of the chief difficulties to be met. A rest from potato for three or four years would probably cleanse infected land" (Cappel, *l.c.*, 1st note). A

Saturation of surface soil.

saturated surface soil is favourable to the disease. On the other hand a trial of the ridge and furrow system to obviate this, did not

Comparison of bed and ridge planting.

prove as satisfactory for the crop, when compared with the bed system of the native cultivators, as was expected. Mr. Mollison suggests that the explanation of this is that the rapid assimilation of food which occurs under Indian conditions of climate is more easily effected where a superabundance of surface moisture is preserved. Such a crop he thinks may, however, have its resistance to disease lowered as a consequence of over-luxuriant growth. Different varieties of potato resist the disease to different degrees. Newly imported English and Kumaun seed gave good results, and the produce was eagerly bought for seed by the native cultivators. Infection probably occurs in two ways, through the seed, and through the soil. The sclerotia are certainly thrown into the soil from rotten stems and must infect it, for

they are admirably adapted to preserve their vitality for long periods. They are probably to be found in the upper layers of the soil in infected lands. "BANGLE" BLIGHT.

76. *Treatment of the disease.*—The treatment suggested, and tried with considerable success, was based on these considerations. In order to avoid seed-infection new seed was imported, and, as already stated, escaped disease. As it was grown on land known to have borne diseased potatoes in previous years, this must have been due to a certain amount of inherent resistance to the disease. Since, however, this power appears to have been possessed by all of the imported varieties, it is, perhaps, more accurate to ascribe the difference in the behaviour of imported and indigenous seed to an abnormal weakness on the part of the latter brought about by unsound cultivation through many years. As in the case of **Phytophthora** disease, the immunity of imported varieties was lost after some years' cultivation. To be effective, in India, as in Europe, change of seed should be continuous. Indeed in India it would appear that deterioration is more rapid than in Europe, whether as a result of bad cultivation or of the climatic conditions I do not know. In view of the fact that by the native system of cultivation in beds, water used in irrigation surrounds the haulms at the seat of infection, namely, near the base, and must thereby assist the progress of the disease, the English ridge and furrow system was tried. Water for irrigation was run along the furrows, and naturally did not wash the base of the stalks. The sets were also planted wider apart than in the native system. The results of this mode of planting were rather contradictory. In some cases a greater outturn per acre was got. In others, where bed planting with the sets wide apart was employed, the results were better than in the ridge and furrow areas. The influence on the progress of the disease was masked by the fact that none of the newly imported seed used in the experiments was much affected. On the whole **Mr. Mollison** recommends growing on ridges. He considers that indigenous varieties, if planted in beds, are more subject to disease than if planted on ridges; while "as regards newly imported good varieties there can be no doubt that the ridge system of planting is best." ("*Text-book on Indian Agriculture*," Vol. III, 1901, page 204.) I have little doubt that flushing the stems on the native system promotes the entry of the parasite into the base and assists its growth when once it has gained the tissues. Finally, sulphate of copper, which had proved a failure when applied to the leaves, was added to the water used for irrigation in order to destroy the disease germs in the soil. The want of success in the earlier experiment was at once explained when the nature of the disease was pointed out by **Dr. Cunningham**. Sulphate of copper could have little effect on a

Treatment by new seed.

Immunity lost in a few years.

Deterioration of seed.

Ridge and furrow system.

Evil of flushing the stems.

Sulphate of copper.

"BANGLE" BLIGHT.

parasite which is firmly established in the interior of the stalk before it gives rise to external symptoms. On the other hand, the sclerotia, which **Dr. Cunningham** considers are the agents by which the soil is infected, are thrown free into the soil on the decomposition of haulms. In this state they can be easily reached by fungicides dissolved in the water used for flushing the fields. Eighty-four pounds of sulphate was used per acre, being added in concentrated solution to the water as it was raised from the well, a measured quantity to each bagful of water. This treatment was successful in diminishing the disease. It is, however, too expensive to be practicable on a large scale.

Soil treatment.

Burning the soil.

77. **Mr. De Joss**, Superintendent at Panchgani, found that burning the soil with vegetable débris, after well turning it up with the plough and exposing it to the sun, gave an alternative method of destroying the source of infection in the soil. He grew several varieties remarkably free from the disease in this manner.

Farm-yard manure after burning.

78. Where either of these methods of soil disinfection is practised plentiful manuring afterwards is to be recommended. The destruction of germs in the soil is a process not unattended with risk. In the treatment many organisms which are beneficial to plant life are destroyed; and recent research goes to show that the part played by these in assisting the growth of plants by providing them with easily assimilable food is very great. They may be, however, in part replaced by the use of farm-yard manure, which contains some of these organisms in considerable quantity.

Destruction of soil organisms.

Burning stalks.

79. One other precautionary measure may certainly be carried out with profit. This is the collecting and burning of all stalks from diseased fields, so as to avoid their rotting on the ground and liberating the internal sclerotia into the soil.

Diseases to which "Bangle" blight is allied.

80. *Diseases resembling "Bangle" blight.*—A number of diseases of potato, presenting resemblances to "Bangle" blight, have been described from time to time in other countries. They all possess the distinguishing character of attacking the stem rather than the leaves or roots. **Frank** ("*Kampfbuch gegen die Schädlinge unserer Feldfruchte*)" mentions four different fungi which have been associated with these diseases: **Verticillium albo-atrum** *Reinke*, **Fusarium pestis** *Sorauer*, **Rhizoctonia** *Solani Kühn* and **Botrytis cinerea** *Persoon.*

Sclerotial disease in Europe.

81. Of these four, the last, or a closely allied species, is believed to be responsible for a considerable amount of damage in Europe. A new potato disease appeared in 1880 in the west of Ireland. **Mr. Worthington Smith** who investigated it found a fungus attacking the stem, of quite a different nature to **Phytophthora.** In 1883 it was found in Scotland and Norway, and the fungus was named

Peziza postuma by Berkeley and Wilson. De Bary considered it to be the same as **Sclerotinia (Peziza) sclerotiorum** *Lib.* The cases which have been described as due to **Botrytis cinerea,** in Germany and elsewhere, are probably also connected with this, since **Botrytis** is merely one of the stages of **Sclerotinia**. The disease is known in Ireland as "yellow blight," and has attracted a good deal of attention there. In its symptoms, especially in the wilting of the green top, and in its association with a fungus which forms sclerotia, it resembles "Bangle" blight. The sclerotia are, however, quite large and are formed externally, instead of within the tissues. The fungus extends from root to root through the soil, attacking many other plants as it meets with them. When the plant is lifted the white threads of the fungus are usually conspicuous on the outside of stem and roots. From these characters, it is probable that the Bombay disease is not identical with "yellow blight."

"BANGLE" BLIGHT.

Different from "Bangle" blight.

82. It is also practically certain that the fungus of "Bangle" blight is not **Rhizoctonia Solani,** since the latter can be recognised by its filaments, which form characteristic enlargements.

Rhizoctonia Solani.

83. To endeavour to gain some further information regarding the cause of the disease I obtained specimens from Poona through **Mr. Mollison** in December 1902.

Further specimens obtained.

84. The tubers showed the characteristic brown "ring" in the interior on section and the stalks were discoloured and shrivelled as described by **Dr. Cunningham.** Within the tissues of some of the stems numerous threads of a fungus were found, chiefly in the vessels, which were crowded with them, but I could not find any sclerotia. The tubers as before showed none of these threads in or near the discoloured area, but in these, and in all the stalks, both those which contained fungus and those which did not, I found a condition which is significant in view of certain recent work on the stalk diseases of potato. A small bacillus was present in great quantity, principally in the vessels, but also in the surrounding cells, either scattered, or forming dense masses almost entirely filling the lumen of the cell. Cultures of this were obtained from both stems and tubers. On cubes cut out of the interior of the latter with a knife at a dull red heat and placed in sterilised flasks, drops of a whitish pus-like substance appeared after some days, exactly as described by **Tryon** in the Australian disease mentioned below. These drops consisted of myriads of the bacillus, which, however, differed somewhat from **Tryon's,** being only about twice as long as broad. As circumstances did not permit of further study of this organism, and no infection experiments were attempted, I do not wish to be taken as suggesting that we have here, rather than in the fungus studied by **Dr. Cunningham,** the true cause of disease. It has, however, recently

Characters of diseased tubers.

Fungus in the vessels.

Bacteria also found.

"BANGLE" BLIGHT.

Parts played by fungi and bacteria, respectively, in certain diseases.

Bacterial disease in America and Australia.

In Europe.

Possibility of bacteria being concerned in "Bangle" blight.

been found that the part played by fungi in the stem diseases of potato has been exaggerated; and that several of the diseases supposed to have been caused by the fungi enumerated above, are really due chiefly to bacteria. Thus Frank, while stating that these fungi are often found together with the bacillus, established by experiment that the latter alone is quite capable of producing the disease. Smith, in America, and Tryon, in Australia, found that the greater part of the damage in these two countries is due to one and the same organism, the Bacillus Solanacearum *Smith*. Prillieux and Delacroix, in France, and Kramer, in Germany, have similarly described bacterial diseases closely resembling "Bangle" blight and sometimes accompanied by a fungus, not in itself capable of causing much harm. It may be said that a bacillary stem disease of potatoes, resulting in the wilting of the green top, is one of the few bacterial diseases of plants established beyond reasonable doubt. If it be eventually shown that "Bangle" blight is of this nature, the fact of seed infection, brought out by experimental cultivation in Bombay, will be explained. For though the fungus is not to be found in the tubers, the bacillus is, and can doubtless pass to the new shoots when they appear.

Farukhabad diseases.

85. In the end of December 1902 Babu Rameshwar Dayal of my office obtained some specimens of a disease which was damaging the crop at Farukhabad. Two diseases are distinguished by the cultivators in this locality. One called "agia" (from *ág*-fire), is said to be endemic, but appears to attack the potatoes known locally as "Desi" only. It will be returned to below under the head of "Early blight." The other, called "pálá" (frost) was doing much damage to "Madrasi" potatoes, and was said to occur in any year when there is but little moisture in the soil.* The seed is sown in September and October and harvested in December to February. The fields receive indigo seed, castor cake and night-soil as manure, and are irrigated from ten to fifteen times. The disease is marked by a withering of leaves and stalks, and a stunting of the growth of the plant. Seed tubers of the "Madrasi" variety and complete plants in all stages of "pálá" were sent to me, and examination showed that all the characters of "Bangle" blight were present in some of them. The seed was marked by a well-defined brown ring on section and the stalks were discoloured and wilted. Fungus hyphæ occupied the vessels near the base of the stalk, and bacteria, resembling

Cultivation in Farukhabad.

"Bangle" blight in Farukhabad.

* Further information and specimens received through the Department of Land Records and Agriculture, United Provinces, in January 1903, made it probable that the cultivators confuse under the name of pálá, "Early blight," "Bangle" blight, and the effects of frost, all of which caused some damage in Farukhabad this year, though nothing, so far as I could ascertain, in any way serious.

"BANGLE" BLIGHT.

those of the Poona disease, were found both in stalks and tubers. The latter were cultivated and gave the same white drops consisting of masses of a short rod-shaped bacillus as above described. Pálá is evidently in part nothing more or less than "Bangle" blight.

Loss in Farukhabad. Use of diseased tubers for seed.

86. Babu Rameshwar Dayal was informed that the yield was only about half of the normal in attacked fields. Tubers of diseased plants are very small, and are preserved for next year's seed. It is not to be wondered at that the disease is endemic, and that the outturn is extremely poor in the attacked fields. The marvel would be if the produce of such seed gave anything approaching to a good potato. Apart from bad seed the cultivation of the district is high.

Probable that "Bangle" blight occurs elsewhere.

87. I do not, for a moment, believe that these few instances exhaust the localities in which "Bangle" blight exists. Information is hard to get on such points, but it is probable that the disease is not restricted to a few provinces, but is widespread throughout the country.

OTHER POTATO DISEASES.

CHAPTER III.

Other Potato Diseases in India.

88. In the same paper in which "Bangle" blight was described, Dr. Cunningham gives an account of three other diseases of potatoes. The first of these he calls "Root-blight caused by the invasion of the tissues by a species of **Pythium**." This was found in the plains of Northern India at Saharanpur, Gurdaspur and Batala, in the Gurdaspur district, in 1893. There was no sign of **Phytophthora** on the leaves or stalks. Furthermore the tubers were perfectly healthy in appearance, with the exception that in some red-skinned specimens there was a narrow zone of bright pink in an area corresponding to that in which the fibro-vascular bundles are distributed, dependent on the presence of a certain number of cells containing a red colouring matter, like that found in the cortical tissues. In the base of the stem and the larger roots a fungus of the genus **Pythium** was found in the cellular tissues and also to a less extent in the fibro-vascular bundles. This genus is allied to **Phytophthora**, but the members of it are much less strongly developed parasites, being in fact in many cases entirely without the power of attacking living plants. The fungus occurred only in the subterranean parts of the plant, but here its threads and spores were abundant within the tissues. The threads of **Pythium** closely resemble those of **Phytophthora**. They have, however, the power of boring their way directly into the cells and not alone between them. The result is usually to set up a moist rot, which, as in the case of **Phytophthora**, is partly the work of bacteria following the fungus. A rot of this sort, starting at the base, usually has, as its result, a total collapse of the plant while the top is still green. The stalk itself remains soft and does not dry up as in "Bangle" blight. The spores in this disease were formed within the tissues, and were of two sorts. One resembled those already described for **Phytophthora**, except that instead of being produced on tree-like branches rising into the air, they were formed singly at the extremity of short stalks within the roots and under-ground portion of the stem. Their germination was not observed but was presumably like that of the other species of **Pythium**, either by means of zoospores or of a germ-filament, in other words very much like that of **Phytophthora**. In **Pythium vexans** *de Bary*, which is in many respects extremely like this fungus, though not known as a parasite, germination by zoospores is rare. The other form of spore found, was a sexually-produced oospore with a thick wall, and probably, like the oospores of allied species, well suited to surviving for long intervals

Pythium disease.

Characters of *Pythium*.

Characters of *Pythium* rot.

Spores.

Sexual or resting spores.

of time in a dormant condition. These oospores were produced in large quantity, and must have been set free copiously into the soil from the rotting haulms and roots. There they would lie until, perhaps, a new crop was planted, when if provided with sufficient moisture, as by irrigation, they would germinate and reproduce the disease. They germinated freely after a short resting period, when placed in water, giving rise to a branched germ-tube which grew to form a new generation of the fungus.

OTHER POTATO DISEASES.

Reproduction by resting spores.

89. Dr. Cunningham did not identify this **Pythium** so as to name it specifically. **Pythium** has been described as the cause of potato blights on more than one occasion. De Bary has shown that **Pythium de Baryanum** *Hesse*, can attack potatoes vigorously. Sadebeck also found a species which appeared to do severe damage near Coblenz. He named the fungus **Pythium Equiseti**, but it is scarcely possible to distinguish it by his description from **Pythium de Baryanum** and it was probably in reality this fungus. From Dr. Cunningham's figures it is quite clear that his species was not **Pythium de Baryanum**, since it differs in a character which is usually considered one of the most important for distinguishing the various species of **Pythium**. This is the size of the oospore and the relative proportion it bears to the cell in which it is formed, or "oogone." In **Pythium de Baryanum**, the oospore entirely fills the oogone, whilst in Dr. Cunningham's species, the figures clearly show that the oogone is much larger than the oospore. I have had an opportunity of examining most of the known species of **Pythium**, and of those I have seen **Pythium vexans** *de Bary* most nearly approaches the figures of Dr. Cunningham. But **Pythium vexans** is not known as a parasite, and de Bary failed to make it attack living plants. It must, therefore, remain a matter of doubt whether the fungus has been described before or not. It is also, as Dr. Cunningham points out, by no means proved that it has anything to say to the disease at all. Since, however, no other cause was found, Dr. Cunningham's recommendations for treatment were based on the assumption that the blight is essentially dependent on the presence of the **Pythium**.

Previous references to *Pythium* diseases of potatoes.

Connection with the disease not proved.

90. *Treatment of the disease.*—The measures suggested by him were, in the first place, the avoidance of all excessive irrigation, and in the second, the careful removal and destruction by burning of all portions of blighted haulms and roots. **Pythium**, like **Phytophthora**, revels in moisture, the more so that it is capable of living in the soil, external to its host plant. There is, in fact, no limit to its existence as a saprophyte (*i.e.*, gaining its nutrition from dead organic matter) whereas **Phytophthora** dies rapidly if not provided with living food in the shape of the potato or one or other of some half-dozen plants. In a saturated soil the reproduction by swimming

Avoidance of excessive irrigation.

Burning of diseased parts.

OTHER POTATO DISEASES.

spores is greatly favoured, while a dry one largely diminishes the possibility of spreading by this means. Again, since resting-spores are formed within the plant tissues, and these can persist from year to year, the destruction as completely as possible of all débris on the fields is clearly indicated. The same result would be attained still more completely were a strict rotation adhered to, so that the crop should not occupy the same field two years in succession. Rotation, however, though so carefully practised with regard to many other crops in India, appears to be a counsel of perfection where potatoes are concerned.

Rotation the best remedy.

"Karrah" blight in Oudh.

91. The next blight mentioned in **Dr. Cunningham's** paper, is known as "Karrah" by the natives of Oudh, where it has caused considerable damage in the neighbourhood of Lucknow. This is a leaf disease, and associated with it two fungi were found. The tissues of the leaves were everywhere permeated by fungus hyphæ, which gave rise to two different forms of spores. The first, and by far the most abundant, of these, consisted of erect unbranched filaments, capped by clusters of large colourless uniseptate spores. These germinated directly in a few instances, but usually each chamber of the spore formed a definite wall within itself, so that it came to contain lying free within it a single nearly circular spore—"as if each of the loculi of the original conidioid bodies became converted into a unisporic sporangium ere germination took place." The second form of fructification presented the characters of **Fusisporium Solani** *Mart.* This, however, was clearly saprophytic, living only on the dead tissues of the leaf and therefore having nothing to do with the cause of the disease. This may have been the case with the other also, and **Dr. Cunningham** concludes that it would be impossible, without further enquiry, conducted locally, to determine the true nature of the blight.

A leaf disease.

Two fungi found.

True nature of the disease not known.

Sclerotial disease of tubers from Poona.

92. Another disease was found by **Dr. Cunningham** in samples of potato tubers received from Poona in 1894. It was due to a fungus whose mycelium penetrated the tubers, and after exhausting their nutritive substances produced an abundance of ovoid sclerotia of a fairly large size. Externally they appeared sound enough, though a little soft, while on cutting them open large irregular cavities were found, lined with a thick coating of white mycelium. The tissues surrounding these cavities were softened, and in advanced cases the whole of the interior was reduced to a pulp. In this the sclerotia were found in large numbers. Experiments were made with this fungus to ascertain its infective power as a parasite. On the leaves of **Ficus stipulata** and **Begonias** a spreading blight was produced by it, the surface of the leaves becoming covered with the filaments which penetrated into the interior through the stomata. On intact potatoes, however, it failed to effect an entry across the thick rind, though

Experiments of Dr. Cunningham.

OTHER POTATO DISEASES.

growing on the surface of the latter freely in a moist atmosphere. When the continuity of the rind was broken by a wound, the raw surface was soon covered with a dense fleece of mycelium while the tissues beneath became disorganised. In these cases, eventually, all the phenomena of advanced disease were reproduced. In the specimens received from Poona the active agent in providing the fungus with a mode of entry was a species of acarus or mite. It was this which formed the irregular cavities above mentioned, and the same pest had been previously found, unaccompanied by any fungus, in specimens from Jullundur received in 1892. The mites alone were capable of causing destruction of the tubers, but the progress of destruction was much more rapid when they found themselves accompanied, as in the Poona samples, by a fungus possessed of definite parasitic properties.

Proof that the fungus causes the disease.

A wound parasite.

Wounds caused by a mite.

93. *Treatment of the disease.*—For treatment Dr. Cunningham recommended keeping the tubers as dry as possible, and burning all those which showed any signs of the disease. The first of these measures will tend to repress the multiplication of both acarine and fungal elements, and the second will ensure the destruction of acari, ova and sclerotia, and prevent the reproduction of both of the causes of the disease.

Keep dry.

Burn all diseased tubers.

Figure 7.—Alternaria Solani *Sorauer.*—A shoot showing the characteristic appearance of "Early blight" (after Galloway).

94. A disease, identical with that known in America by the name of "Early blight," has quite recently been brought to my notice from Farukhabad. It is that which has been referred to on an earlier page as known to the cultivators, in the vernacular, as "Agia." Specimens and local information regarding it were obtained for me through

"Early blight" in Farukhabad

OTHER POTATO DISEASES.

Cause.

A leaf disease.

Diagnosis.

the Department of Land Records and Agriculture, United Provinces. A few fields only were diseased this year (1902-1903), and even in them the damage was not considerable. "Early blight" is caused by a fungus, **Alternaria Solani** *Sorauer* (**Macrosporium Solani** *E. & M.*) which, like **Phytophthora**, attacks the leaves. It can be easily distinguished from **Phytophthora**, however, especially in the earlier stages. Figure 7 shows the characteristic appearance of circumscribed brown spots which grow at the circumference, and are usually marked by concentric rings indicating the stages of growth. It is, as the name implies, a disease of early appearance, thus contrasting with "Bangle" blight which does little harm until the crop is approaching maturity. Progress is slow as compared with **Phytophthora**, and the leaf may live for a week or more. Eventually it withers, turning a light brown, not blackish as in **Phytophthora** disease. In a bad case all the young leaves are attacked and the plant dies from lack of nutrition. Figures 8 and 9 show the peculiar spores, characteristic of **Alternaria**, by which the disease is spread. Treatment is chiefly by Bordeaux mixture in America, where alone the disease is severe. In India, there is no indication at present of its becoming a dangerous pest, though I have on many occasions found in hastening the destruction wrought by **Phytophthora**. Bordeaux mixture would offer the best prospect of success should the treatment ever become imperative. Short of that, since **Alternaria** is a "weak parasite," *i.e.*, one unable to produce much injury, except where the vitality of the plant is diminished from some other cause, high cultivation is the one means clearly indicated of lessening the liability to attack.

Attacks the young crop.

Progresses slowly.

Cause of death.

Treatment by Bordeaux mixture.

Not dangerous at present in India.

Alternaria solani a weak parasite.

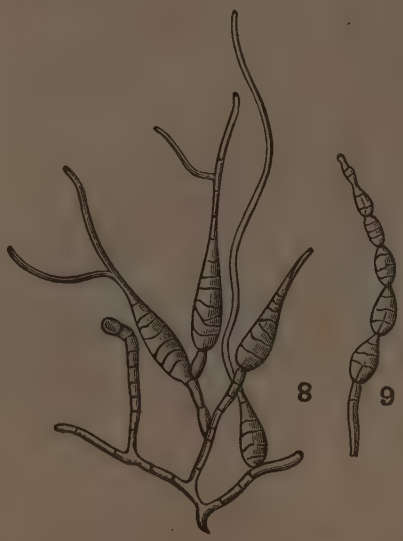

Figure 8.—**Alternaria Solani** *Sorauer.*—Spores from a diseased leaf (after Sorauer).

Figure 9.—Chain of spores of **Alternaria Solani** (after Sorauer).

G.I.C.P.O.—No. 504 R. & A.—14-7-1903.—145—P. M. M.

All communications regarding THE AGRICULTURAL LEDGER should be addressed to the Editor, The Reporter on Economic Products to the Government of India, Calcutta.

The objects of this publication (as already stated) are to gradually develop and perfect our knowledge of Indian Agricultural and Economic questions. Contributions or corrections and additions will therefore be most welcome.

In order to preserve a necessary relation to the various Departments of Government, contributions will be classified and numbered under certain series. Thus, for example, papers on Veterinary subjects will be registered under the Veterinary Series; those on Forestry in the Forest Series. Papers of more direct Agricultural or Industrial interest will be grouped according as the products dealt with belong to the Vegetable or Animal Kingdom. In a like manner, contributions on Mineral and Metallic subjects will be registered under the Mineral Series.

This sheet and the title-page may be removed when the subject-matter is filed in its proper place, according to the letter and number shown at the bottom of each page.